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(54) UNIDIRECTIONAL FLUID FLOW MEMBRANE

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No. OF CLAIMS 8

ABSTRACT OF THE DISCLOSURE:

An unidirectional fluid flow membrane in the form of a sheet of porous plastics material comprising a multitude of interconnected pores that together define passages suitable to allow a gas such as air to flow. The sheet of plastics material has one face heat-treated to partially close the passages to an extent sufficient to prevent a liquid such as water from flowing across the sheet toward the other face, whereby this sheet acts as a check-valve with respect to the liquid only. Owing to its unidirectional structure, this membrane can advantageously be used as overpressure valve in a life- or sea- jacket or as purge valve or exhaust diaphragm in an underwater mask, snorkel or regulator.

The present invention relates to an unidirectional fluid flow membrane useful as check-valve, overpressure valve, purge valve, exhaust diaphragm, escape valve and the like, and to a method of manufacturing the same.

Numerous equipments, particularly underwater equipments such as life- or sea- jackets, masks, snorkels, regulators and filtering systems, include at least one check-valve in their structure to allow a gas such as air to flow in one direction while preventing water from flowing in the other direction. Thus, every life- or sea- jacket incorporates at least one overpressure valve to allow the pressurized gas used for inflating it to escape over a threshold pressure of about 1 lb. Most of the masks or snorkels used for diving also each incorporate at least one purge valve to allow any water entering inside the mask or snorkel to be expelled from the same when the diver breathes out by the nose. Similarly, all the regulators used by the divers each incorporate an exhaust diaphragm to allow air to escape and any water swallowed by the diver to be spitted out by the same without having to remove the mouth piece from his or her mouth. In each case, it is of course necessary that water be prevented from flowing in the other direction and from entering into the inflated life or sea jacket, the mask or the mouth.

All the check-valves used up to now in these underwater equipments are of the mechanical type and include spring or resilient means as return-means for the valve. After several years of use or storing, the spring or the resilient material generally becomes weak or it jams. In both cases, this results in malfunctioning of the equipment that may be very prejudiciable and even extremely risky when the equipment is especially designed for being used in case of emergency.

In accordance with the present invention, it has now

been found that the above mentioned drawback can be completely overcome by using an unidirectional fluid flow membrane allowing air or another gas to flow in one direction while preventing water from flowing in the other direction, instead of using a spring valve. Indeed, as such a membrane does not comprise any mechanical part, it cannot jam or be damaged in any way.

The present invention therefore proposes an unidirectional fluid flow membrane for use as overpressure valve, purge valve, exhaust diaphragm or escape valve, which membrane is in the form of a sheet of porous plastics material having a thickness ranging from about 1/16 to 1/2 inch and comprising a multitude of interconnected pores that together define passages suitable to allow air or another gas to flow. The sheet of plastics material has one face heat treated to partially close the passages to an extent sufficient to prevent a liquid such as water from flowing across the sheet toward the other face, whereby this sheet acts as a check-valve with respect to the liquid only.

Preferably, the interconnected pores of the sheet of plastics material have a size ranging from about 8 to 250μ.

When the unidirectional membrane according to the invention is to be used as overpressure valve in a life-or sea-jacket, the sheet of plastics material preferably has a thickness of about 1/2 inch and the interconnected pores have a size of 8 to 10 μ, the membrane thus having a threshold pressure of about 0.75 to 1.0 lbs.

When the unidirectional membrane according to the invention is to be used as purge valve or exhaust diaphragm in an underwater mask, snorkel or regulator, the sheet of plastics material preferably has a thiskness of about

1/16 inch and the interconnected pores have a size of about 120µ to allow any water inside the mask, snorkel or regulator to be unilaterally expelled therefrom when the diver breathes out by the nose or the mouth.

When the unidirectional membrane according to the invention is to be used as escape valve in a pumping filtering system, the interconnected pores preferably have a size of about 35µ.

In each case, the sheet of plastics material can advantageously be made from a material selected from the group consisting of high density polyethylene, ultra-high molecular weight polyethylene, polypropylene and fluoro carbon.

Suitable sheets of plastics material that can be used, for example, as starting material for the manufacture of unidirectional fluid flow membranes according to the invention are those sold under the trademark "POREX" by the U.S. firm Glasrock Products Inc. of Fairburn, Georgia. The sheets of plastics material supplied by this firm in thicknesses varying from 1/16 to 1/2 inch or more, have omnidirectional interconnected pore sizes varying from 8 to 500µ depending onthe polymers used. These sheets can be used as disc filters or column chromatography, electrode gel, ion-exchange resin or under-drain supports. To make such sheets of plastics material unidirectional and therefore useful in accordance with the present invention, it has been found that it was necessary only to glaze one face thereof at a temperature slightly inferior to, preferably less 1 or 2^{O}C than, the melting point of plastics material. Such a glazing gives the sheet of plastics material a differential porosity, that is a porosity that is different from one face of the sheet to the other.

Therefore, the present invention also proposes a method of manufacturing an unidirectional fluid flow membrane of the type defined hereinabove, which method comprises the step of glazing one face of a sheet of porous plastics material comprising a multitude of interconnected pores that together define passages suitable to allow air or another gas to flow, at a temperature slightly inferior to the melting point of the plastics material in order to partially close the passages to an extent sufficient to prevent water from flowing across the sheet from the one face toward the other face.

As aforesaid, the purpose of this glazing which is applied to an already formed sheet of plastics material is essentially to reduce the porosity at the surface of one face of the sheet to an extent sufficient to prevent water from flowing across the sheet of plastics material from this one face to the other. This reduction of porosity is obtained as glazing causes shrinking of the pores in the vincinity of the surface of this one face by non-reversible, thermical expansion of the plastics cells forming the sheet and/or slow melting of the edges of the same.

When use is made of "POREX" as porous plastics material, glazing can be carried out in a single step, simply by bringing the sheet of plastics material into contact with a hot plate. If necessary, the hot plate may be provided with hot air injection nozzles to diffuse heat from the plate through the plastics material.

When use is made of another kind of porous plastics materials, particularly non-hydrophobic porous plastics materials, it is generally preferable to treat the material with an inorganic acid in order to prevent wetting of the pore surfaces and thus re-entry of water through the membrane.

Actually, if the plastics materials used in the membranes according to the invention are not hydrophobic they generally allow water, particularly soapy water, to pass through the membranes as the tiny pores at the surface of the sheets of plastics material can no more "trap" small bubbles of air or anyother gas that prevents water from flowing, as they can owing to their surface tension when they are still dried. As soon as their pore surfaces are wetted, the membranes thus allow water to continuously pass therethrough in both directions.

In order to prevent such a drawback, the membrane made of non-hydrophobic porous plastics material must therefore be subjected to treatment with an inorganic acid before glazing. This treatment can be carried out with, for example, a solution of 40% HCl per volume. The acid makes the surface of the pores non-slippery and thus renders the material completely hydrophobic.

The invention and its various advantages in use will be better understood with reference to the following description taken in connection with the accompanying drawings in which:

Fig. 1 is a schematic, enlarged view of an unidirectional membrane according to the invention, shown in cross-section;

Fig. 2 is a view of an inflated life-jacket provided with a membrane according to the invention as overpressure valve;

Figs. 3 and 4 are perspective and cross-sectional views of the membrane used as overpressure valve in the

life-jacket shown in Fig. 2;

Fig. 5 is a cross-section view of a mask or snorkel provided with a membrane according to the invention as purge valve; and

Fig. 6 is a cross-sectional top plane view of a dried-regulator for use in diving, provided with a membrane according to the invention.

The unidirectional fluid flow membrane 1 according to the invention as shown in cross-section in Fig. 1 is made of a sheet of porous plastics material 3 comprising a multitude of interconnected pores 5 that together define passages suitable to allow air or anyother gas such as CO_2 to flow therethrough. The sheet 3 has a thickness T that may vary from about 1/16 to 1/2 inch depending on its use. The interconnected pores 5 have a size that may vary from about 8 to 250 depending on the proposed use for the membrane.

The thickness of the sheet and the size of its pores of course depend on its use. If the membrane is to be used as overpressure valve, it will be necessary to use a sheet 3 having a substantial thickness with pores 5 of a very small size. If the membrane is to be used as purge valve, it will be necessary to use a sheet having a small thickness with pores of bigger size.

The sheet 3 is preferably made of polypropylene as this material provides better gas flow although other plastics material such as high-density or ultra-high molecular weight polyethylene or fluorocarbon could also be used.

The membrane 1 is generally made starting from an omnidirectional sheet 3 of porous plastics material of the type sold under the trademark "POREX" by the firm Glasrock Products Inc. of Fairburn, Georgia. To make it unidirectional,

the sheet 3 is subjected to thermical treatment. More especially, one face 7 of the sheet 3 is glazed at a temperature slightly inferior to the melting point of the plastics material for a period of time sufficient to reduce the porosity at the surface of this one face 7 to such an extent that water is prevented from flowing across the sheet 3 from its one face 7 to its other face 9.

Glazing of the face 7 of the sheet 3 causes the particles of plastics material adjacent to face 7 to expand in a non-reversible manner or to slowly melt as is shown in Fig. 1 and thus to reduce the size of the pores on this face 7 only. As a result of this reduction in size, the surface tension of the pores is substantially increased at the face 7 and this surface tension increase prevents water from entering into face 7 and flowing from this face 7 to face 9.

As a matter of fact, glazing here makes the sheet 3 completely hydrophobic, in a better manner than any acidic solution could do.

The reduction in size of the pores 5 at the surface of the face 7 of the sheet 3 however does not prevent air or anyother gas to flow from face 9 to face 7 and water or anyother liquid to be expelled under suitable pressure in the same direction.

The unidirectional structure of the membrane 1 with respect to water makes it particularly useful as check-valve in many kind of underwater equipments in place of the spring valves used up to now.

Figs. 2 to 4 show a life-jacket 11 provided with an unidirectional membrane 1 as overpressure valve.

As everybody knows, the life-jacket 11 as every

life-jacket must include at least one overpressure valve to allow the pressurized gas contained in the cartridge 13 and used for inflating the bag 15 in case of emergency to escape over a predetermined threshold pressure which is generally of 1 lb. This overpressure valve is necessary to avoid that the bag 15 be over-inflated and eventually damaged with air leaks or by complete explosion.

To replace the conventional overpressure spring-valve that may become weak or jam, use is therefore made of an unidirectional membrane 1. The membrane is glued and/or sealed directly onto the surface of the reinforced edges 17 of an opening 19 provided in the bag 15 at a suitable location, and protected by a grid 16. Of course, the heat-treated face 7 of the membrane 1 must be external to the bag 15 to prevent water from entering into the same.

To ensure a suitable threshold pressure of about 1 lb, use can be made for example of a heat-treated, POREX sheet of polyethylene having a thickness of 1/2 inch with pores of about 8 to 10μ.

Fig. 5 shows a mask 2 of a conventional type, comprising a rubber skirt 27, a strap 29 and a front glass 23 fixed to the skirt by a plastic trim 25. In accordance with the invention, the mask 21 is advantageously provided with an unidirectional membrane 1 acting as purge valve. The membrane 1 is located just under the nose of the diver in a hole provided in the rubber skirt 27 to allow any water entering inside the mask to be expelled from the same when the diver heavily breathes out by the nose.

Of course, the heat treated face 7 of the membrane 1 must be external to the skirt 27 to prevent external water from extering into the mask.

To allow easy expulsion not only of air but also

of water our of the mask, use can be made, for example of a heat-treated, POREX sheet of polypropylene having a thickness of 1/16 inch with large pores of about 120 μ.

Last of all, Fig. 6 shows a regulator 31 of a conventional type comprising a rubber mouth pieces 33, a front cap 35 made of plastics and/or metal and a low pressure air-supply 37 in the form of a hose connected to a pressurized air bottle via a pressure reducer (not shown). In accordance with the invention, this regulator 31 is rendered "dry" simply by using two separate membranes 1 and 1'. The membrane 1 forms the back cap of the regulator and allows air together with any water having entered the regulator to be expelled by the diver during his or her expiration. The membrane 1' acts as a plug for closing the mouth piece 33 and is designed to prevent sea water from entering into the regulator when the diver removes it from his or her mouth. However, this membrane 1' must also be so designed as to allow water swallowed by the diver to be expelled by the same during his or her expiration, that is under a certain overpressure. Of course, the heat treated faces 7 and 7' of the membranes 1 and 1' must be external to prevent sea water from entering into the regulator.

As membrane 1, use can be made, for example, of a heat-treated, POREX sheet of polypropylene having a thickness of about 1/16 inch with large pores of about 120 μ. As membrane 1', use can be made, for example, of a heat-treated POREX sheet of polypropylene having a thickness of about 1/16 inch with very large pores of about 250μ to prevent sea water from entering into the regulator while allowing swallowed water to be expelled when strongly breathing out. Of course, the unidirectional membrane according to the invention can be used for other purposes in which unidirectionality is requested. Thus, by way of example, the membrane according to the invention

can also be used as a check-valve in a pumping filtering system such as those used for the pool. In this case, the pores of the membrane however must have a large size of, for example 35 μ to avoid generating too much loss of pressure inside the system.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. An unidirectional fluid flow membrane in the form of a sheet of porous plastics material having a thickness ranging from about 1/16 to 1/2 inch and comprising a multitude of interconnected pores that together define passages suitable to allow air or another gas to flow, said sheet having one face heat-treated to partially close said passages to an extent sufficient to prevent a liquid from flowing across the sheet toward the other face, whereby said sheet acts as a check-valve with respect to the liquid only.

2. A membrane as defined in claim 1, wherein the interconnected pores of the sheet of plastics material have a size ranging from about 8 to 250μ.

3. A membrane as defined in claim 1, for use as overpressure valve in a life- or sea- jacket wherein the sheet of plastics material has a thickness of about 1/2 inch and the interconnected pores of said sheet have a size ranging from about 8 to 10μ to obtain a threshold pressure of about 0.75 to 1.0 lbs.

4. A membrane as defined in claim 1 for use as purge valve or exhaust diaphragm in an underwater mask, snorkel or regulator wherein the sheet of plastics material has a thickness of about 1/16 inch and the interconnected pores of said sheet have a size of about 120μ to allow any water inside the mask, snorkel or regulator to be unilaterally expelled therefrom when breathing out.

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5. A membrane as defined in claim 1 for use as escape valve in a pumping filtering system, wherein the interconnected pores of the sheet of plastics material have a size of about 35μ.

6. A membrane as defined in claim 3, 4 or 5, wherein the sheet of plastics material is made from a material selected from the group consisting of high density polyethylene, ultra-high molecular weight polyethylene, polypropylene and fluoro-carbon.

7. A method of manufacturing an unidirectional fluid flow membrane as defined in claim 1, comprising the step of glazing one face of a sheet of porous plastics material comprising a multitude of interconnected pores that together define passages suitable to allow air or another gas to flow, at a temperature slightly inferior to the melting point of the plastics material in order to partially close the passages to an extent sufficient to prevent water from flowing across the sheet from said one face toward the other face.

8. A method as defined in claim 8, wherein the glazing temperature is less 1 or 2^{o}C than the melting point of the plastics material.

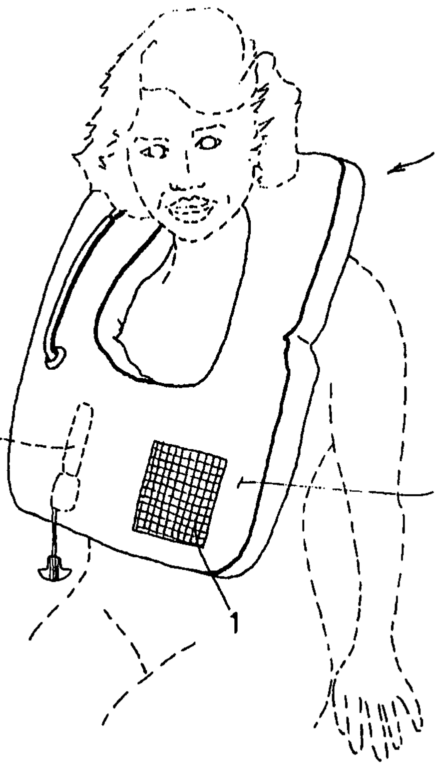

Fig. 2

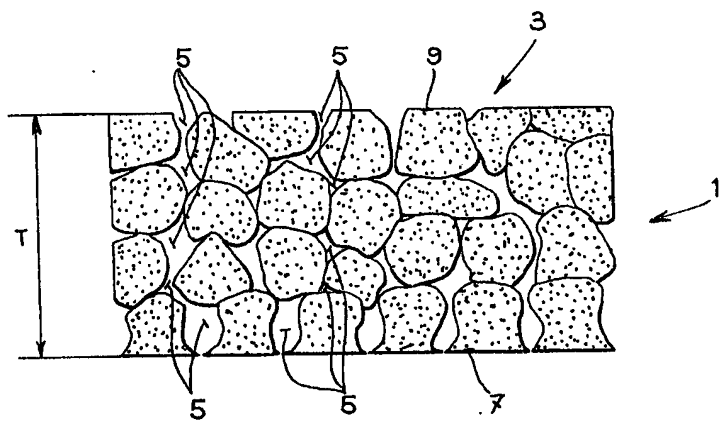

Fig. 1

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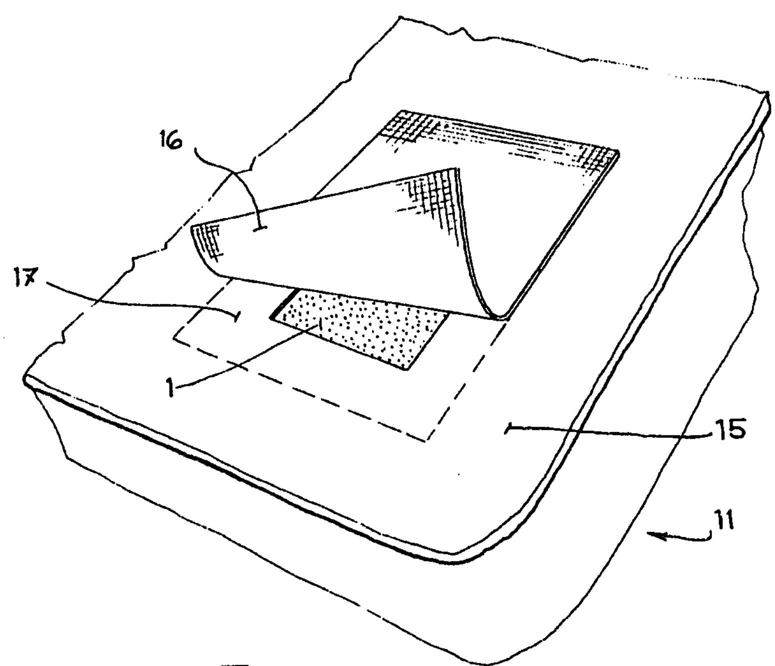

Fig. 3

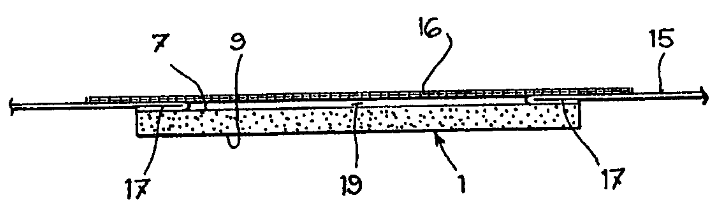

Fig. 4

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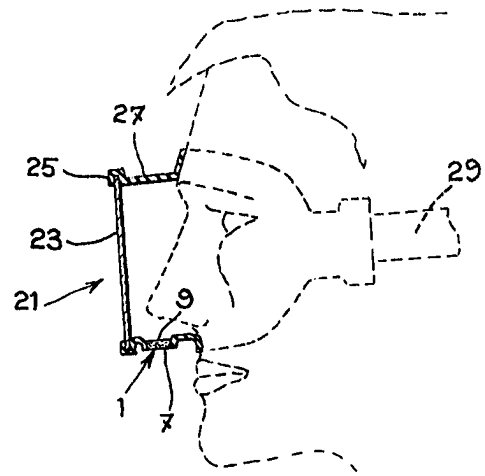

Fig. 5

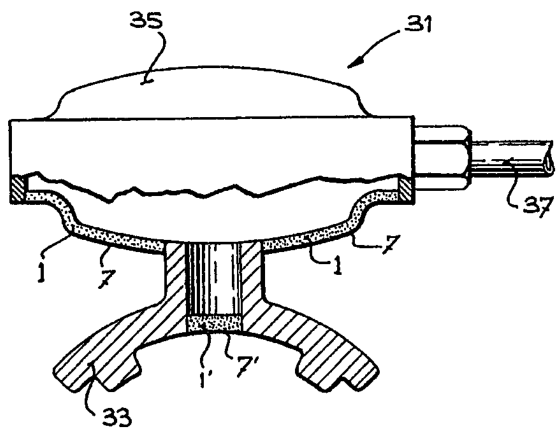

Fig. 6

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